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IRRIGATION PRACTICES IN GROWING ALFALFA

BECAUSE OF the rapidity of its growth and the number of cuttings obtained during a season, alfalfa requires more water than most crops. Nevertheless water should be applied carefully in order to avoid wasting it and possibly injuring both crop and land.

There are several methods of applying water to alfalfa, their suitability depending on the character of soil and subsoil, climate, water supply, size of farm, and other factors. The most common are the border, check, and flooding methods.

Flooding the field from laterals or small ditches is a common method in the Rocky Mountain States. It can be used to advantage on slopes that are too steep for other methods. It costs little to prepare fields for flooding, and the method is adapted to the use of small streams of water.

For irrigating by the border method, a field is divided into long narrow strips, by low levees, extending usually in the direction of the steepest slope. This method can be used best where large streams of water are available to the farmer.

For irrigating by the check method, a field is divided by low levees into plots of nearly level land. The most favorable conditions for this method are light, sandy soils on an even slope of 3 to 15 feet to the mile or heavy soils on which it is necessary to hold water for some time in order that it may percolate to the desired depth.

No fixed time can be recommended for watering alfalfa. In general it is best to irrigate as late as possible before the cutting and again after the crop has been removed if water is then needed. The appearance of the alfalfa is an aid to the farmer in determining when water is needed, a light-green color indicating that the plants are in no immediate need of water.

This bulletin is a revision of and supersedes Farmers' Bulletin 865, Irrigation of Alfalfa.

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IRRIGATION PRACTICES IN GROWING ALFALFA

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Contents

Experience in the growing of alfalfa shows that it thrives best in the soil and climate of the arid and semiarid regions, provided water is supplied by irrigation. It prefers a deep, well-drained loam soil, abundant sunshine, and a dry atmosphere. Certain varieties do well in Imperial Valley, Calif., below sea level, while other varieties thrive in the San Luis Valley of Colorado, 7,500 feet higher.

More than one-third of the acreage devoted to alfalfa in the United States is under irrigation in the 17 Western States.

THE ROOTS OF ALFALFA

Some knowledge of the location, extent, and functioning of the roots of alfalfa is desirable to enable the farmer to apply to the soil within the root zone the proper quantity of water at the right time and in the right way.

The topsoil should be moist enough from recent rains or an irrigation at seeding time to supply the water needed by the plant until a number of true leaves appear and the taproot attains a depth of about 2 feet. The long, slender taproot of the young plant has a number of tiny branches throughout its length; for them moisture must be available if a satisfactory crop is to be produced. Hence an adequate soil-moisture content should be maintained, if possible, in all parts of the root zone.

The normal distribution of roots of a mature plant grown in deep loamy soil free of hardpan or ground water may be expected to conform

[1] On July 1, 1939, the Soil Conservation Service took over most of the irrigation investigations formerly conducted by the Bureau of Agricultural Engineering.

somewhat closely to that indicated in figure 1, *A*. This example shows the weight of the roots in each 6 inches depth of soil of a plant grown at University of California farm, Davis, Calif., under soil, climatic, and moisture conditions which produced an average seasonal yield of 8.71 tons an acre on 18 plots for a period of 4 years. The stems of representative plants were cut off just below the crown, and the weight of roots in each 6-inch layer of soil was determined. The fact that the roots near the surface, especially in the top foot of soil, represent a high percentage of the weight of all the roots is accounted for in part by the larger and heavier portion of the taproot in this stratum, which under normal conditions contains also the largest number of branch roots. Ordinarily each foot of soil within the root zone is amply provided with branch roots. By this distribution the plant is enabled to derive the larger part of its soil nutrients from the upper stratum of

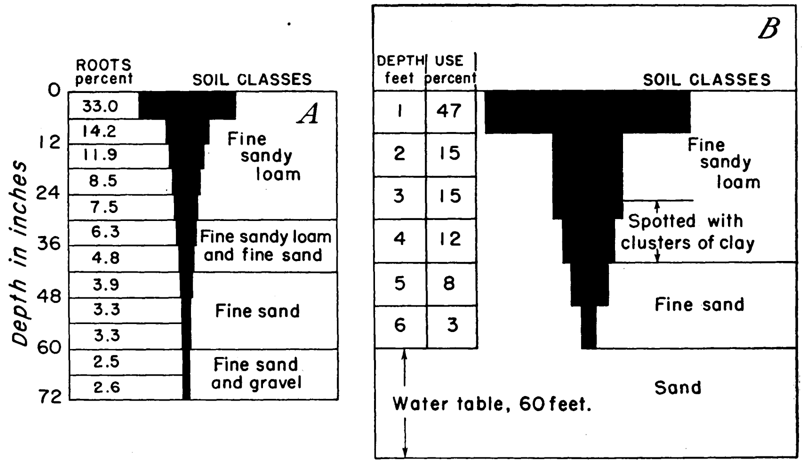

FIGURE 1.—Results of plot experiments. *A*, Distribution of alfalfa roots by weight, under favorable conditions, as demonstrated at Davis, Calif. *B*, Water from various depths of soil used by 3-year-old alfalfa, as demonstrated at Scottsbluff, Nebr.

soil, which generally is most fertile and best aerated, and to obtain part of the water it needs from the deeper roots in wet soil. As a further protection against drought the taproot normally extends beyond the limits indicated in figure 1, *A*. Its objective seems to be a soil that is always moist, and it has been known to penetrate the subsoil to a depth of 30 feet in order to attain it. However, while such deep taproots may sustain plant life, they alone will not supply sufficient moisture for a profitable crop.

Recent studies carried on at the Scottsbluff field station, in western Nebraska, by the Division of Irrigation and the Division of Western Irrigation Agriculture, show results similar to those obtained at Davis, Calif. In the Nebraska studies, by a method of soil sampling, moisture changes at the various depths were recorded throughout the season. From these moisture changes the use from each foot of depth (1 to 6 feet) was calculated. The data shown in figure 1, *B*, were obtained each year for 5 years from two one-fourth-acre plots of third-year alfalfa. The alfalfa was irrigated once for each cutting of

hay, and all rain was considered as being used by the surface foot. The average production per acre over the 5-year period was 5.2 tons of field-cured hay.

Sometimes if the water table stands too high for a considerable time and the lower part of the taproot is continuously submerged, the taproot eventually decays, causing the plant to suffer. This unfavorable condition is illustrated in figure 2, which outlines the distribution of the feeding roots of alfalfa with a water table 3 feet below the surface. Where an infertile hardpan underlies a shallow soil, similar results often occur. The plants have no reserve-root zone from which to derive additional moisture and nourishment to overcome the effects of drought and other severe climatic viscissitudes.

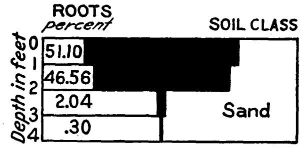

FIGURE 2.—Distribution of alfalfa roots with a water table 3 feet below ground surface.

The chief function of the roots of alfalfa, as of any other plant, is to furnish a quantity of water and nutrients in solution adequate to its requirements. In the case of alfalfa these are very heavy. Under ordinary conditions about 750 tons of water is absorbed by the roots, drawn up through the stems, and mostly transpired by the foliage, for each ton of cured hay harvested.

PREPARING NEW LAND FOR SEEDING AND IRRIGATION

The first step in preparing land for agriculture in the arid portion of the West is to remove the native desert plants. Where such pioneering is still possible, the smaller varieties of sagebrush and greasewood can be removed by deep plowing when the soil is moist. When the growth is 20 to 60 inches high it is removed usually by "railing,"

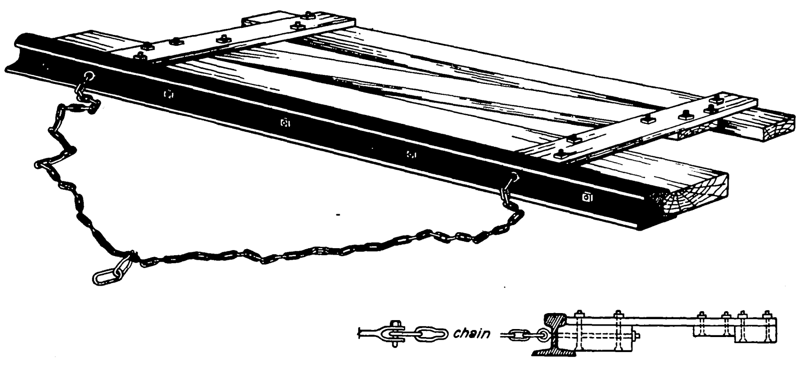

FIGURE 3.—A 10- to 15-foot section of a 90-pound railroad rail adapted to break down heavy sagebrush.

grubbing, and plowing. Railing (fig. 3)[3] consists in hitching a strong team to each end of a railroad rail and dragging it across the field. This process results in breaking off the shrubs at the ground surface. Subsequently they are raked into windrows and burned. On lands densely covered with heavy shrubs it may be necessary to do a second

[3] Reproduced from the following publication: BEAN, R. P., DEVELOPING NEW LAND UNDER IRRIGATION, Wash. Agr. Expt. Sta. Pop. Bul. 136, 28 pp., illus. Nov. 1926.

railing in the opposite direction, after which the brush is again raked and burned. The field (especially the knolls) is then deeply plowed, and the upturned roots are gathered and burned.

Where large units of desert land are involved bulldozers are frequently used, and tractor power has largely superseded horsepower.

For the removal of mesquite (which varies from a straggling, spiny shrub under adverse conditions to a widely branched tree under favorable conditions), and other similar vegetation native to southwestern deserts and valleys, tractor power as well as the older hand-grubbing method is used.

Preliminary operations in preparing land for irrigation do not always consist merely in getting rid of native vegetation. Sometimes sand dunes or other high spots must be lowered and depressions filled before a properly graded surface can be obtained. The plow and the light scraper have been the implements most commonly used for this kind of work, but in recent years heavy scrapers and levelers operated by tractors have become popular, largely because of the rapidity with which they can do the work.

In preparing new land for irrigation it is seldom wise to complete the operation during the first season. The land is first roughly prepared and a cereal crop sown, irrigated in a crude way, and harvested. Meanwhile the roots of shrubs have decayed enough to be removed, filled-in soil has settled, and a permanent job of surface grading is possible, preparatory to seeding a perennial crop such as alfalfa.

In some western valleys alfalfa seeding usually follows many years of continuous cropping to wheat, corn, and other small grains, or other crops. Shallow plowing is the common practice in growing cereals, and when the operation is repeated year after year a plow sole, or cultivation hardpan, is apt to form. This is not a true hardpan but rather a compaction of the finer particles of soil beneath the cultivated stratum. Deep plowing breaks up the plow sole, and generally improves the physical properties of the soil. By following this practice, worn-out grainfields, which did not yield a profitable crop of grain, have been made to produce satisfactory yields of alfalfa.

FARM SYSTEMS OF IRRIGATION

In planning a farm system of irrigation, or irrigation lay-out, the slope and configuration of the surface, the character of the soil and subsoil, the quantity and quality of water available, and the manner in which it is delivered deserve careful consideration. The method of irrigation adopted is based mainly on these factors. A knowledge of surface slopes can best be obtained by a contour survey in which lines of equal elevation are run across the farm at intervals of about 6 inches in elevation. These reveal the highest as well as the lowest parts of the slope in any direction. The farmer's delivery head gate can then be located at or near the highest point and the farm divided off into the requisite number of fields and lanes, a suitable site being reserved for the farmstead. The boundaries of fields and lanes also determine generally the location, direction, and length of the various permanent farm ditches, pipes, flumes, or other conduits. The character of the soil can best be determined by making borings with a soil tube or soil auger and examining the borings in each foot of depth. The water-right contract or certificate pertaining to the farm indicates the

quantity of water available, and the regulations, and bylaws of the company or other agency furnishing it indicate the manner in which it is delivered.

In the future irrigation development of arid lands, much labor and expense might be saved and greater profits obtained by following a

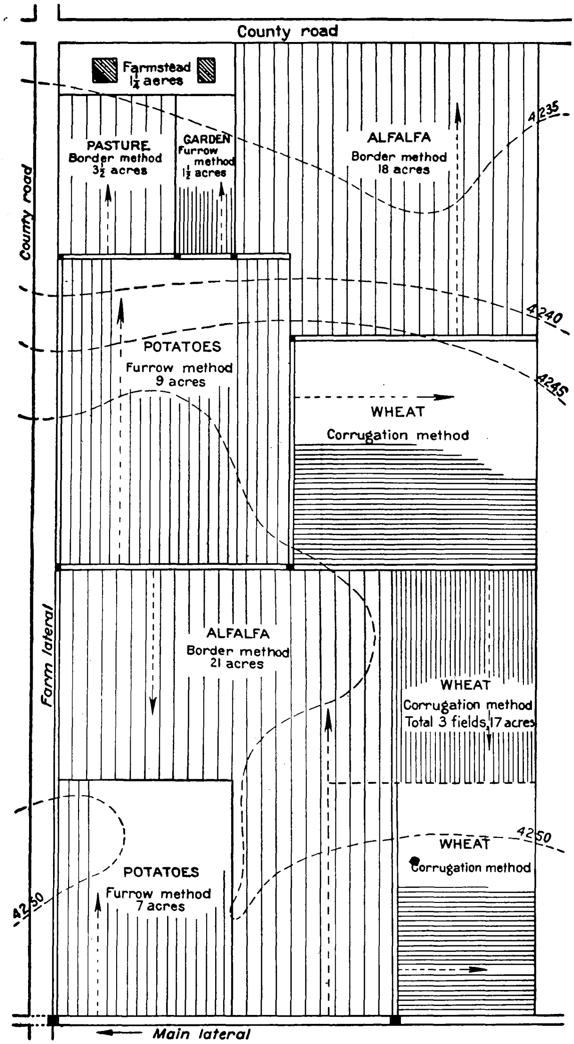

FIGURE 4.—Lay-out of an 80-acre Idaho farm on which three methods of irrigation are used. (The survey of such a farm lay-out should develop contours at 6-inch intervals. For illustrative purposes, however, the figure shows 5-foot contours only.)

skillfully prepared plan for the irrigation lay-out of each farm. The execution of this plan need not be completely carried out during the first or even the second year of cultivation. The chief value of such a plan would be in giving the farmer a proper start and in guiding his subsequent operations.

Besides the factors already discussed, crops and profits influence the shaping of the irrigation lay-out since a valuable crop yielding high returns calls for a more expensive and permanent lay-out than a cheap crop yielding low returns. Hence it is not feasible to adopt one standard plan of lay-out for many farms unless conditions are exceptionally uniform. As a rule each plan is adapted in design and construction to serve best the needs of the farm for which it is intended. The plan shown in figure 4 is therefore intended to represent merely the general arrangement and the adaptation of the methods to local conditions.

FARM DITCHES

Water is distributed over an irrigated farm during the crop-growing season by means of ditches, flumes, or pipes. The ditches are of two general kinds—temporary and permanent. Temporary ditches are

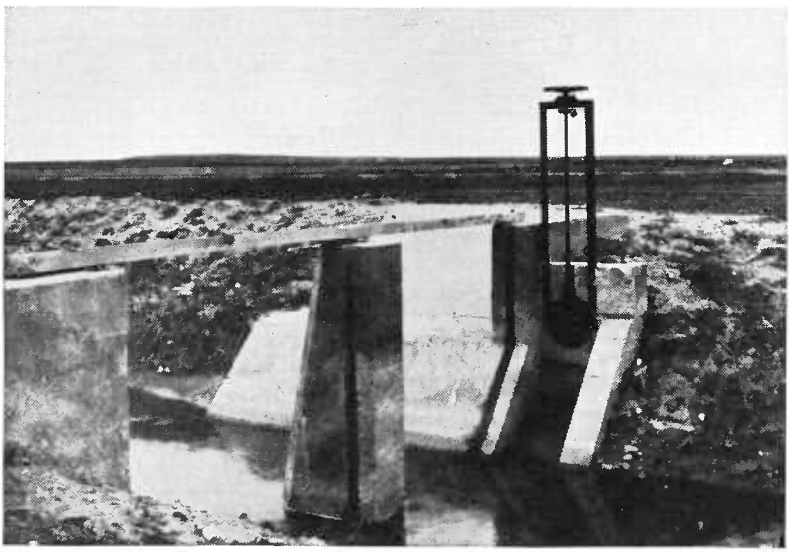

FIGURE 5.—A farmer's head gate and canal check. This figure pictures a substantial structure but a faulty practice. The elevation of the head gate necessitates the use of flashboards to raise the water high enough to flow into the farm lateral, but this operation causes losses by increasing the percolation into the banks of the channel. Another fault is that the first few or lower flashboards vary in length and are not interchangeable. In such a structure all the boards should be of equal length.

formed in cultivated fields and are required for only a season, or less, after which they are leveled down and filled in by plow and cultivator in preparation for harvesting the crop. Permanent ditches are located usually along the margin of fields and are operated from year to year until a change in the farm lay-out becomes necessary. To this latter class of ditches belongs the supply ditch which conveys water from the canal, stream, or other source of supply to the highest point of the farm.

The flow of water in farm ditches should not be rapid enough to cause erosion or sluggish enough to necessitate extra expense in providing large channels. Ordinary firm loam will not erode under a

mean velocity of 2½ feet per second; for convenience in handling, this is about as fast as water should flow in such channels. Some materials erode under slower velocities. Fine sand without any colloidal material to bind its particles is likely to erode in velocities of 1½ feet or less per second, sandy loam at 1¾ feet, and fine loam and silt at 2 feet per second.

The grade of ditch regulates the flow, but the proper grade to adopt in any given case depends also on the volume of water to be carried. The smaller the volume, the steeper is the grade required for a given velocity. For most farm ditches, slopes varying from 1 to 3 inches per 100 feet are most satisfactory.

The capacity of the supply ditch and other permanent ditches depends on the method adopted in irrigating the soil and also on the character of the water supply and the regulations governing its delivery to users. If furrows are to be used to wet the soil, a relatively small quantity of water, or head, varying from 1 to 2½ second-feet, is required. Flooding from field laterals requires heads of from 1½ to 3 second-feet, while for the border and check methods of irrigation 1 to 10 second-feet, or more may be used depending upon the sizes of the areas between the borders or checks and the character of the soil.

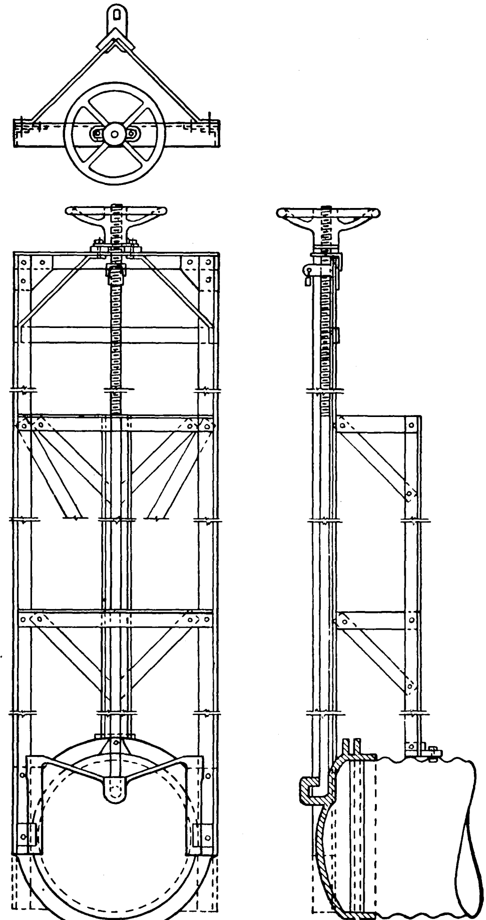

FIGURE 6.—Metal head gate attached to corrugated pipe.

Some of the structures which constitute a necessary part of a farm irrigation system are head gates or turn-outs, measuring devices, division boxes, flumes, pipes, and check gates. These may be built of wood, concrete, steel, or combinations of these materials. A combined canal check and farmer's head gate built of concrete is shown in figure 5. A common type of head gate made of steel is sketched in figure 6.

In making small farm ditches after the ground is plowed, a ditch plow or lister is often used, followed by a small V-shaped crowder (fig. 7) and more or less hand dressing by shovels.

Medium-sized ditches may be made by wing plows or graders.

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Ditches generally need cleaning early in the spring and may also have to be cleaned at intervals later in the irrigation season. In a ditch which erodes, the undercut banks need shaping, and in a ditch

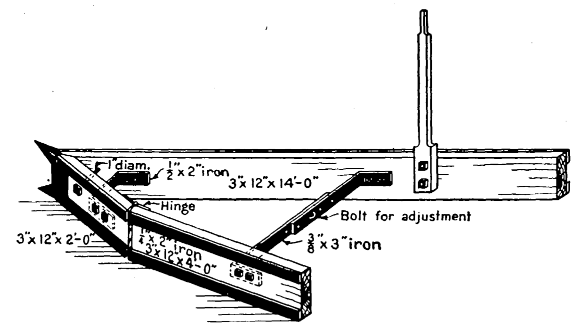

FIGURE 7.—An adjustable crowder.

which silts, the deposits have to be removed. They can be removed by hand shoveling or by any of the methods used in the original construction.

METHODS OF IRRIGATING ALFALFA

The methods of applying water to alfalfa differ widely because of the diversity of climates, soils and subsoils, topography, the nature of water supplies, the sizes of farms, the funds available for preparing the land for water, the principal crops grown, and the early training and environment of irrigators. The most common methods are the border method, the check method, flooding from field laterals, and the corrugation method, with their modifications. Other less common methods such as the portable-pipe method and the subirrigation method are practiced in a few localities.

THE BORDER METHOD [4]

Preparing a field for irrigation by the border method consists essentially of dividing it into long, narrow plots or "lands" by low, flat levees which extend in the direction of the steepest slope (provided this slope is not so steep as to cause washing of the soil or difficulty in spreading water). The purpose is to confine the water in the separate strips (fig. 8). The bed of each strip is carefully made level from side to side. If the contour of the natural surface is such that a uniform slope cannot be obtained without much grading, a curved gradient is not objectionable, provided there is no adverse grade. The size of the strip depends mainly on the grade, the head of water used in flooding the strip, and the type of soil. For heads varying from 1 to 8 second-feet and for the three main classes of soils, namely, sands, loams, and clays, Beckett and Brown, of the University of California, recommend the dimensions given in table 1. They also recommend as the most desirable grades for strips when measured in inches per 100 feet: 1¼ to 3½ inches for clay soils, 2¼ to 7 inches for loam soils, and 3½ to 12 inches for sandy soils. In all types of

[4] Described in Farmers' Bull. 1243, the border method of irrigation.

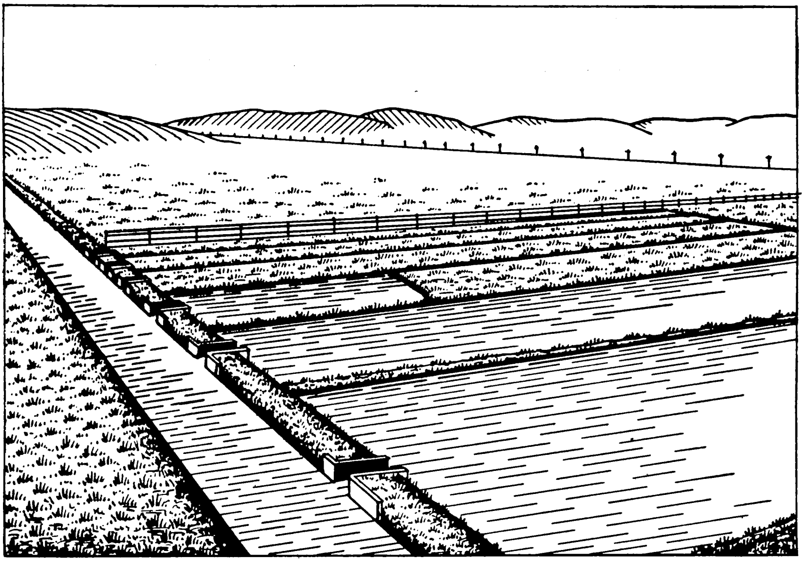

FIGURE 8.—Irrigation by the border method.

soils, but especially in sandy soils the upper 20 to 30 feet of each strip should be formed without grade so as to permit the water to spread entirely across the strip before moving down the slope.

TABLE 1.—*Border-strip dimensions for three classes of soil*

Head (*second-feet*)	Sand		Loam		Clay	
	Width	Length	Width	Length	Width	Length
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
1	20 to 30	200 to 300	30	300 to 400	30	440 to 660
1 to 2	30 to 40	300 to 400	30 to 40	440 to 660	30 to 40	660
2 to 4	30 to 40	440	40	440 to 660	50	660 to 800
4 to 8	40	440 to 600	50	660 to 880	50	880 to 1,320

The water to irrigate each strip is taken from the head ditch extending across the upper edge of the field and is controlled by an outlet box or border gate, although the gates are sometimes omitted to save in first cost of preparing for irrigation where the soil is not so light as to permit excessive washing. Check gates, canvas dams, or metal tappoons are used to hold up the water in the head ditch, causing it to flow into the strips. In many sections the temporary devices are giving way to permanent structures, although the latter in many cases interfere with cleaning the ditches and increase its cost.

The border method is confined chiefly to the irrigation of alfalfa, pastures, other forage crops, and small grain, and in its various modifications is used extensively in Arizona, New Mexico, California, and, to a less extent, in Idaho, Utah, Montana, Oregon, Washington, and other Western States. It can be used best under canals which deliver water to users in large streams, since the smallest head that can be applied successfully is seldom less than 1 or 2 second-feet,

while heads of 5 to 8 or even 10 second-feet are common. It is adapted especially to light, open soils, into which water percolates rapidly, as the use of a large stream confined between borders makes it possible to force water over the surface without great loss by percolation. Border gates may be made of wood, a type of which is shown in figure 9. Untreated lumber is short-lived, however, and for permanent structures concrete is more economical although the

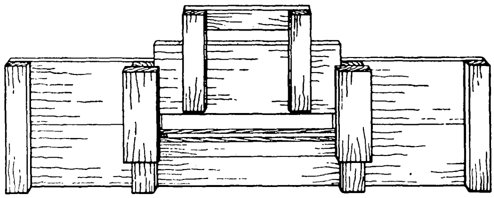

FIGURE 9.—Border gate of wood.

first cost may be greater. A simple and inexpensive check gate in a head ditch is shown in figure 10.

In the case of a farm in Sacramento Valley, Calif., the strips or lands were formerly, on an average, about 50 feet wide by 900 feet long, but in recent years the widths have been reduced to 35 and 40 feet and the lengths to about 600 feet. Each border levee, when newly made, has a base 7 feet wide and is 12 inches high but settles to

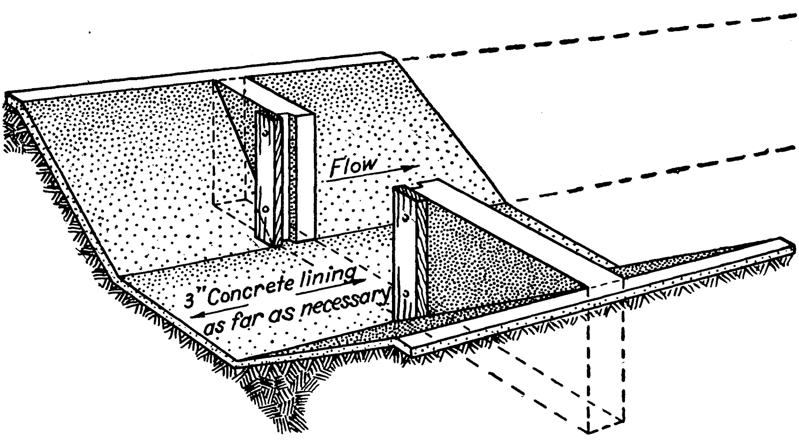

FIGURE 10.—Concrete check gate in head ditch.

about 10 inches before the first crop is harvested. The bed of each strip is leveled crosswise and slopes regularly from top to bottom. In preparing the surface the soil was disked and roughly graded. The location of each border was marked either by drag or by making a furrow. Sufficient earth to form the border was obtained by skimming the surface with scrapers. The scraper teams began next to the head ditch and worked down. They crossed and recrossed the field at right angles to the borders, and as a scraper passed a border marking, its load was dumped. Each scraper width of the borders was made up of two loads, but the last load overlapped the first by half the width

of the scraper. The surface of each border was then leveled to an accuracy of 0.1 or 0.2 foot. The levees when first built were rough, irregular, and steep. They were cut down to a uniform grade by a reversible disk and then harrowed.

As noted, the size of strip and the head of water turned into it are more or less governed by the character of the soil. In sandy soil the borders are spaced from 20 to 30 feet apart and are made from 300 to 400 feet long if the head is fairly large, so as to wet the surface rapidly before much water is wasted by deep percolation. In retentive clay soils which absorb water slowly, longer runs are necessary, and a small quantity of water is allowed to run for a longer time. Sometimes in heavy soils low cross dikes are formed from side to side between the borders, 100 feet or more apart, to pool the water and thus cause deeper moisture penetration.

THE CHECK METHOD

In preparing land for the check method nearly level plots are surrounded with low levees, and water is conducted to each by means of a ditch and check box or gate. The spaces enclosed may be laid out in straight lines in both directions, so that their levee borders form a series of rectangles, squares, or irregular areas as conditions may require; or the levees may follow more or less closely the contour lines of the natural surface of the ground, thus forming contour checks. The most favorable conditions for this method are a light, sandy soil on a comparatively even slope of 3 to 15 feet to the mile, supplied with an irrigation head of ample size. This method is used also on heavy soils, where it is necessary to hold the water on the surface until it has percolated to the desired depth.

In California not only does the form of the checks vary, but their size as well, some of the smaller checks being less than one-half acre in area, while some of the larger contain more than 2 acres.

The long side of each check should be on the flat slope and the short side on the steep slope. A fall of 3 to 5 inches between adjacent checks is best; usually it can be obtained by properly adjusting the width of checks. The length of each basin will depend on the lengthwise slope as well as the location of the supply ditches. The field should be laid out in such a way that the levees may be built with a minimum handling of dirt. Rectangular checks possess many advantages over irregular contour checks, but if much good surface soil has to be removed in order to build the former, the advantages may be more than outweighed by the damage caused by grading and the extra cost.

On the west side of the San Joaquin Valley, Calif., the land to be seeded to alfalfa is almost invariably formed into contour checks. The supply ditches are about 600 feet apart, and levees are built midway between them. The sides of the checks conform in a measure, but not exactly, to the natural contours, having a difference in elevation of 0.3 to 0.4 foot. Under ordinary conditions of soil and relief the cost of preparing dry-farmed land for check irrigation averages about $25 per acre. Uncultivated desert land covered with shrubs is likely to cost 30 percent more.

In the Modesto and Turlock irrigation districts the feed ditches are designed to carry large heads of 5 to 12 second-feet. These large heads are used by the farmers in turn for short periods, the time de-

pending upon the acreage served. In the smaller checks a head of 5 second-feet will suffice, and if more water is available two or more checks may be irrigated simultaneously. Five second-feet flowing on a check containing 1 acre would cover it to a depth of about 5 inches in 1 hour. The skillful irrigator begins with the highest checks and works down, for the reason that all water escaping through gopher holes or broken levees may be recovered and applied to dry checks. To reverse this order might result in overirrigating the lower checks.

The chief advantage of the check method is that one man can attend to a larger volume of water and can irrigate 7 to 15 acres in 10 hours, making the cost of applying water less than that of any other method, except possibly the border method. To counterbalance this important advantage, there are several handicaps which western farmers should consider. These are the removal of a considerable quantity of surface soil to form the levees, which frequently decreases the yield on the graded spots; the extra cost of preparing the land; the damage done to farm implements in crossing levees; and the fact that this method is not well adapted to a rotation of crops.

FLOODING FROM FIELD LATERALS

Flooding the surface of the ground from field laterals or small ditches is a common method of irrigating alfalfa. In Nebraska, Colorado, Wyoming, Montana, Utah, and Nevada, and to a less extent in other Western States, forage and cereal crops are irrigated in this way. This manner of wetting dry soil originated, it is believed, in the Mountain States, and has been gradually extended so that now it is firmly established and is regarded as the method best suited to certain conditions. It can be profitably used on slopes that are too

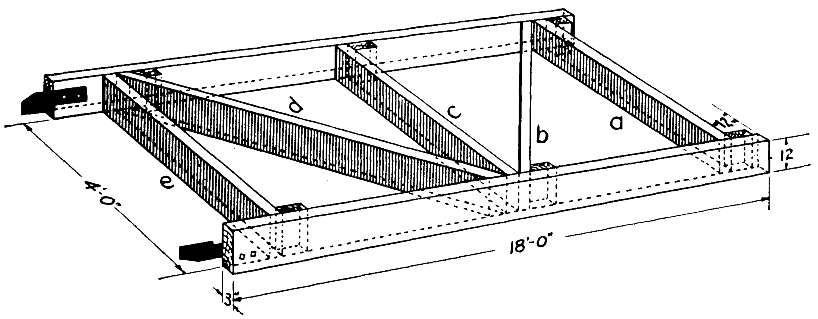

FIGURE 11.—Home-made drag, or leveler: *a*, *b*, *c*, *d*, and *e* are shod with ¼- by 4-inch steel edges.

steep for other methods. In fact the slopes to which its use are limited may vary all the way from 5 to 250 feet or even 300 feet per mile. The cheapness of this method is another feature which recommends it to the farmer of limited means. Ordinary raw land can be plowed and prepared for flooding at an expense of $9 to $15 an acre. Furthermore, the method is adapted to the use of small water supplies. In the Mountain States and other sections where the irrigation systems have been planned and built to deliver water in comparatively small streams for use in flooding or in furrows, water users should be certain that the larger volumes required for checks and borders can be se-

cured before going to the expense of preparing their fields for either of these methods.

In grading the land for flooding it is not customary to make many changes in the natural surface. Only the smaller knolls are removed and deposited in the low places. An effort should always be made, however, to fit the farm laterals into the natural slope and configuration of the tract so as to bring the water to the high places. On steep slopes the laterals may be less than 50 feet apart; on flatter slopes, 200 feet or more. Whatever the spacing, it is always desirable to have the intervening slope as nearly uniform as possible. When the land in its natural state is uneven, the rough grading can be done by a scraper. If the field in its natural condition is comparatively smooth and level a drag or leveler, such as the one shown in figure 11,

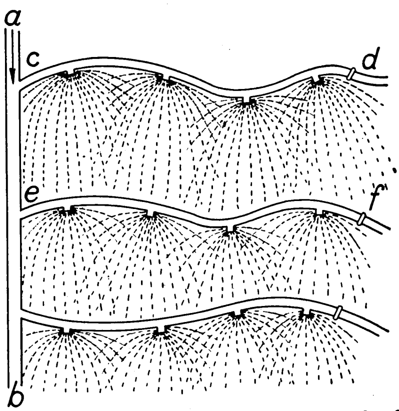

FIGURE 12.—A common method of locating field ditches in the Mountain States.

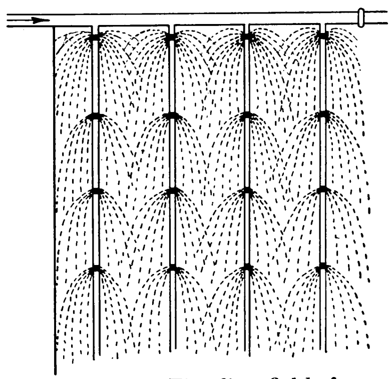

FIGURE 13.—Flooding fields from parallel field ditches.

serves the purpose fairly well, and such an implement is used for smoothing the land after each plowing.

The location of the field laterals used in irrigating by the flooding method varies too widely to admit the adoption of a standard plan, but figure 12 shows an arrangement of field laterals common to many irrigated areas. A supply ditch, *ab*, provided with suitable drops and check gates, is built on one side (usually down the steepest slope) of the field, and the laterals *cd* and *ef* branch from it across the slope, nearly on a contour, with a grade of 1 to 3 inches per 100 feet. These laterals are spaced 75 to 250 feet apart and may be made with the ordinary plow, lister, V-ditcher, or other equipment used for farm ditching. On lands of considerable slope, the dirt should be thrown on the downhill side, so as to provide adequate banks. The size of the laterals is governed by the available head, but on steep slopes and on soil that erodes readily small heads are best. Figure 13 illustrates another common method of irrigation.

In some areas near Berthoud, Colo., the land is naturally of uniform, even slope, and little grading has been necessary to prepare the fields for irrigation. Heavy timber or iron drags are used to smooth the surface after it has been plowed so that the water will spread evenly. These implements are built in various ways and of whatever material

is available. Discarded railroad rails are sometimes used, two being coupled parallel about 30 inches apart. A team is hitched to each end of the drag upon which the driver rides. Going over a field once with such an implement usually is sufficient to make the surface uniform and smooth. The proper location for field laterals is evident to experienced irrigators without the use of surveying instruments, though in fields where the fall is slight it often is necessary to have a topographical survey made and the laterals located by an engineer. In this section field laterals are so located that they cover the highest parts of the field, and for alfalfa they are spaced from 165 to 330 feet apart.

The head required for flooding from field laterals in northern Colorado varies from 2 to 3 second-feet and is divided between two or three laterals. Canvas dams are used to check the water in the laterals and force it out over the banks and down the slopes of the field. Usually in less than 3 hours the upper foot of soil is thoroughly moistened.

In Montana, where clover and alfalfa fields are to be flooded, the field ditches usually run across the field on a grade of 3 to 4½ inches per 100 feet. The spacing between ditches varies with the slopes, the smoothness of the surface, and the volume of water; but 80 feet is about an average. The stream used is seldom less than 1½ or more than 4 second-feet, the larger heads being divided between two or three ditches. A canvas dam is first inserted in each ditch or set of ditches, 75 to 100 feet below the head of the lateral. The water is then turned into each channel and flows as far as the dam, by which it is checked, and as a consequence it rises and flows over the low places of the lower bank, or through openings made with a shovel. When these small tracts have been watered, the canvas dam is moved down the lateral 75 to 100 feet, and again inserted in the channel to serve the next tract. In some sections it is customary to use two dams, one being placed below the other before the first is removed.

Manure or earth dams sometimes take the place of the movable canvas dams. After the ditches have been made, coarse manure is placed in small heaps within each ditch channel at suitable intervals, and each heap is covered with earth on its upper face to a depth of 1 to 2 inches. When this check has served its purpose it is broken, and the water flows down until stopped by the next check. In some instances permanent wooden check boxes are inserted in each lateral. The thorough irrigation of 4 acres is considered a good 12 hours' work for one man. By using a head of 2 to 2½ cubic feet per second, two men can irrigate 7 to 10 acres in 24 hours.

In the Salt Lake Basin the heads of water used by the irrigators of alfalfa vary considerably with the flow of the streams. Heads of 4 to 6 cubic feet per second are common in the spring, while later in the season, when the streams are low, they are reduced to 1 to 3 cubic feet per second. A field usually is divided into strips 200 to 500 feet wide by laterals extending across it. A permanent wooden check box or a canvas dam is inserted in the main supply ditch below each cross ditch, causing the water to flow into the cross ditch. Thence it is spread over the surface through small openings in the ditch bank, and any excess water is caught by the next lower ditch. In this way each ditch serves a double purpose, acting as a drainage channel for the land above it and as a supply channel for the land below.

In summarizing the advantages of the flooding method, it may be said that in first cost it is one of the cheapest; it is adapted to the delivery of small volumes of water (1 to 2 second-feet) in continuous streams; it is particularly well adapted to forage and cereal crops of all kinds; it does not require removal of the topsoil from the high places to fill up depressions; and firm soil can be watered successfully even when located on steep and irregular hillsides.

Its chief disadvantages are the fatiguing labor required to handle the water, the small area which one man can irrigate in a day, the difficulty involved in applying water after dark, and the unequal distribution of water on the field unless more than average care is exercised. The last-mentioned objection is important, since uneven distribution decreases crop returns and wastes water.

THE CORRUGATION METHOD

In that part of the Columbia River Basin comprising the major portions of Oregon, Washington, and Idaho, irrigating the surface soil by flooding is not generally practiced. Instead, the corrugation method is commonly used. This method consists of allowing small streams of water to flow through a series of narrow, shallow furrows or corrugations. This method is more fully described in Farmers' Bulletin 1348, The Corrugation Method of Irrigation.

The spacing of the corrugations depends chiefly on the lateral movement of the soil moisture. In tight soils the lateral spread of

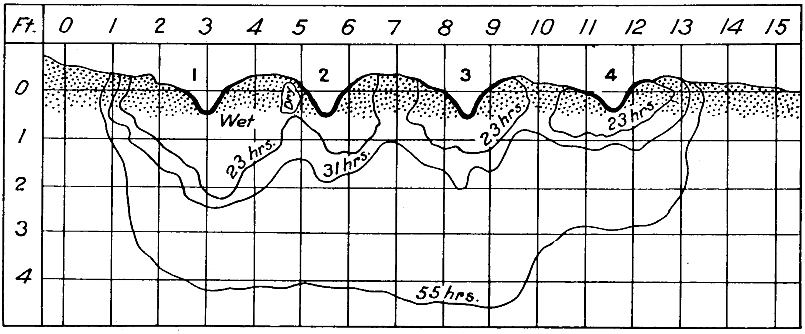

FIGURE 14.—Distribution of soil moisture from corrugations.

water may not exceed 8 or 9 inches, in which case the spacing of the corrugations is limited to 16 or 18 inches. In open porous soils the lateral spread of water may be 18 to 24 inches, and the corrugations are proportionately farther apart. It is well, however, to have the horizontal movement of water overlap to some extent to insure a thorough wetting of all the soil in the root zone; and in ordinary loam soils the corrugations are usually not more than 3 feet apart.

The corrugation method permits the distribution of soil moisture by capillarity and gravity. In lava soils a 12-hour run is usually sufficient to wet the soil in the root zone. In less permeable soils the time required may be much longer, and on more permeable soils much shorter. In the experiment illustrated in figure 14 the water had reached a depth of 1½ feet below the bottom of corrugation 1 at the

end of 23 hours, and in 8 more hours had sunk about 6 inches farther. Corrugations 1 and 2 were 2½ feet apart, and the water from them united in 23 hours to form a continuous curve. Corrugations 3 and 4 were 3 feet apart, and for 23 hours the wetted area of each remained distinct. At the end of 31 hours the wetted sections of all had united. At the end of 55 hours after the irrigation was begun, the water had penetrated to a depth of 4½ feet.

The alfalfa grown in the Yakima Valley, Wash., is practically all irrigated by means of corrugations. The common practice is to run the furrows across the entire width or length of a field, and in consequence their length varies from 330 feet or less in small fields to 1,320

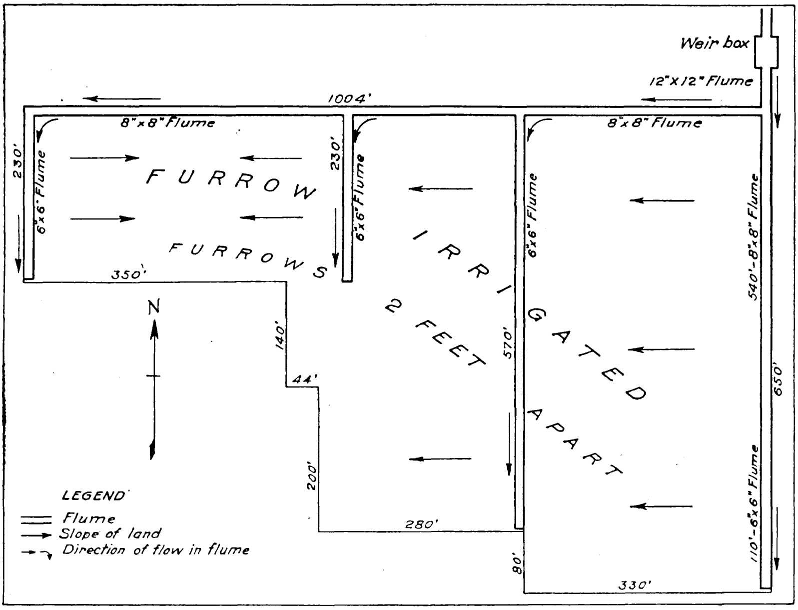

FIGURE 15.—An alfalfa field at Kennewick, Wash., irrigated by the corrugation method.

feet in large fields. Such furrows are usually too long, and their use is not recommended. Farmers object to cutting up a field by head ditches, but in a climate like that of the Yakima Valley in midsummer by far the most essential element in plant production is water, and all other considerations should give place to it. Extending the length of a corrugation much beyond 600 feet not only increases the loss but renders a uniform distribution more difficult to secure. Except in rare cases, this distance should be regarded as the limit for the length of furrows. In light, sandy soils having a porous underlying gravel stratum the length may well be reduced to 150 feet. The use of long furrows on sloping land should be avoided. Long runs require large streams of water, which may result in serious loss of soil by erosion or washing.

Figure 15 shows the manner of dividing an alfalfa field for the corrugation method at Kennewick, Wash. Wooden head flumes, either 8 by 8 inches or 6 by 6 inches, are placed along the upper boundary of

each strip. Auger holes are bored through one side of the flume flush with the floor at points where water is to be delivered to the heads of furrows. A short piece of lath revolving on a nail, or a small galvanized iron slide gate, controls the flow from each opening. Where the grade is steep, a cleat nailed crosswise to the floor of the flume just below each opening will dam back the water and increase the discharge. Flumes are used where the slope is so great that head ditches would erode badly or where the soil is very sandy and the seepage losses from earth ditches would be too great. Ordinarily, however, notches cut in the banks of field ditches allow the water to enter the

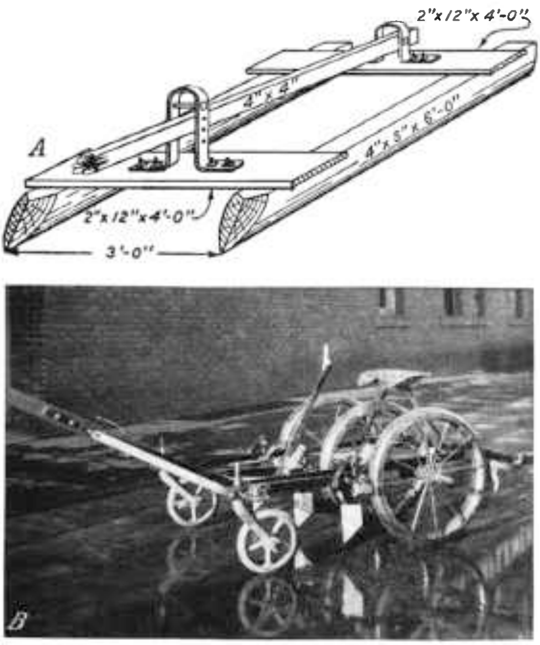

FIGURE 16.—Implements used to make corrugations. *A*, Home-made furrowing sled, and *B*, a corrugator mounted on wheels.

corrugations during the irrigation of such crops as alfalfa, other forage crops, and small grain.

Often the water is distributed to the furrows through wooden spouts or spiles set in the bank of an ordinary ditch. These head ditches when in operation are divided into a series of level sections by means of drop boxes which hold the surface of the water at the desired elevation. The spacing of these structures depends on the grade of the head ditch. Spouts are made usually by nailing together four laths. In some communities a special lath is available. This lath is somewhat heavier than the one used as backing for plaster walls, being ½-inch thick, 2 inches wide, and 3 feet long. Four of these when nailed together cost about 7 cents, and each spout in place costs about 13 cents. Assuming that they are spaced 4 feet apart, the spouts for a square tract of 10 acres would cost $43, or slightly more than $4 per acre. In some irrigated areas the lumberyards carry material for making irrigation spiles. This material is cut so that two pieces nailed

together form a spile, square on the outside, but having a round hole. On sloping land these spiles may furnish too large a stream for each corrugation and they can be modified by using one-half a spile with a lath for the other side.

Tin tubes, ½-inch in diameter, one to each furrow, have sometimes been used instead of the wooden tubes. When these tubes are set ½-inch below the water surface, each tube discharges about 0.1 miner's inch, which is about right for a slope of 3 percent. The length of the tin tubes is governed by the size of the ditchbank. The cost of tin tubes 2 feet long is about $5.50 per hundred. In many places neither flumes nor tubes are used. Water is taken through cuts in the ditchbank and divided among the corrugations as evenly as possible by directing it with a shovel. This practice reduces the cost of preparing the land for irrigation, but it increases the cost of applying water, and does not insure an even distribution.

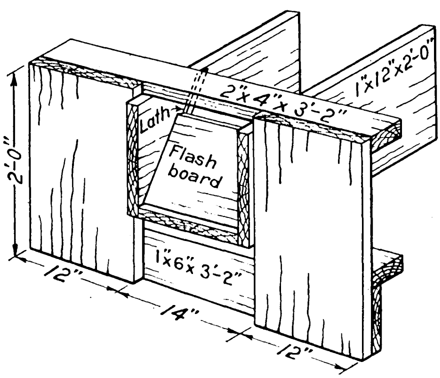

FIGURE 17.—Check box made of lumber.

Numerous implements, of either commercial or home manufacture, are used in making corrugations. Figure 16 shows two specimens, each of which has merit and, if properly constructed, will do its work well. When used on old alfalfa fields, because of the interference of heavy roots, sturdiness is an especially desirable quality in this implement.

For the irrigation of most of the crops grown in the vicinity of Twin Falls, Idaho, the feed ditches are laid out across the field as nearly parallel as possible, on a grade of 2 to 6 inches to 100 feet, and 300 to 500 feet apart. Corrugations are made in the direction of the greatest slope and approximately at right angles to the feed ditches. From the upper end of the field downward, a wooden check is inserted in the ditch at the end of each fall of 12 inches. Thus, if the ditch has a fall of 4 inches to 100 feet the checks are placed 300 feet apart. Each check box is provided with a removable flashboard which, when in place, backs the water to the next check above and at the same time permits the surplus water to flow over its top to supply the checks below.

The tubes are inserted in the lower ditchbank about 3 inches below the water level established by the flashboards when in place. These tubes are inserted while the check is full of water in order that all may set at the same level and that water may be available for puddling. The flow from each tube may be divided among several furrows. Ordinarily a 40-acre farm will require about 30 check boxes and 1,800 tubes. The check box shown in figure 17 calls for 17 board feet of lumber.

IRRIGATING ALFALFA WITH PORTABLE PIPE

In southern California, where many fields of alfalfa are irrigated with water pumped at high expense, great care is exercised to prevent its waste. Concrete pipe lines are laid to convey water from the pumping plants to the fields. These are 10 or 12 inches in diameter. The head lines, along the high sides of fields, are provided with stands about

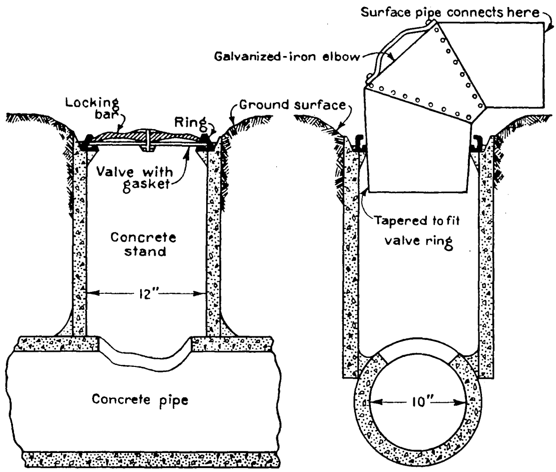

FIGURE 18.—Riser showing valve or elbow connection for surface or pipe delivery.

100 feet apart. A type of stand, or riser, used commonly is illustrated in figure 18. A section of 12-inch concrete pipe is cemented to the supply pipe. This is provided with a removable valve, permitting the insertion of a tapered 8-inch galvanized-iron elbow, to which the distributing pipe can be attached. As shown, the top of the stand and valve is several inches below the general ground surface so as not to obstruct mowing machines. Another type favored recently in some

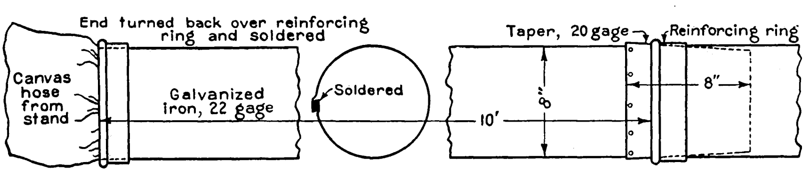

FIGURE 19.—Portable slip-joint metal pipe.

sections is a portable hydrant. This is clamped to the concrete stand and is readily transferable.

In many instances water is forced through the pipe line by the pump, and usually an open overflow standpipe of appropriate height is placed in the line near the pump to relieve the pressure on the pipe line when valves are closed suddenly.

Portable slip-joint pipe is attached to the stands in turn, and through it water is conveyed to all parts of the field (fig. 19). This pipe is made of galvanized iron, usually 20 or 22 gage. It is 8 inches in diameter and is assembled in sections of several lengths, but the

shorter lengths of 10 feet have been found to be most durable and are preferred. The sections of some pipe of latest manufacture are 10 feet long, each being made of a single sheet of metal.

With a stream of 600 gallons per minute, one man can irrigate 2½ acres in a 10-hour day. To irrigate a field the water is used from one stand for a strip equal in width to the distance between stands and in length from the head to the foot of the field. Since without reservoirs there must be an outlet for the water whenever the pump is in operation, it is best to have one stand open temporarily while the surface pipe is being connected to another. The best way to irrigate with surface pipe is to begin applying water at the upper end of the strip, and proceed toward the lower end by adding sections of pipe.

When care is used there need be no waste and no draining of surface water to prevent scalding. If too much water is being applied, it will flow down the field, and as the work approaches the lower side, it is easy for the irrigator to make proper allowance for the surplus. When one strip has been watered he begins at the upper end of the line by carrying the pipe across to the new location, section by section. The second stand is opened and the new connection made before the first stand is closed. The leakage at the joints of pipes is slight, and the loss is not of consequence since it occurs on the land being watered.

The advantages of irrigation with portable pipe may be summarized as follows:

A small stream may be handled effectively over a large area, and the irrigator may apply the stream on any part of the field he desires.

Losses which otherwise would occur by seepage in the conveyance of water over a field are prevented, and loss through gopher and squirrel holes is much reduced.

The fact that no field laterals are required effects a direct saving in the crop-producing area of a field, as well as in the time required to construct and repair these laterals.

With no laterals and the surface of the land free from obstructions, crops can be harvested with greater ease and with less wear and tear on farming machinery.

Land can be irrigated with little or no preparation, although it is better to level it to some extent if it is at all uneven.

The disadvantages are:

Initial cost is high, especially where underground pipes form a part of the system.

Depreciation is high even with careful handling.

Leakage cannot be wholly prevented.

The labor involved is burdensome.

It is necessary to have pressure head on the pipe in order that a fair-sized stream may be carried in conduits of medium sectional area.

Field irrigation with portable pipes undoubtedly is impracticable in many sections of the West on account of the high cost and other disadvantages. However, other sections possessing a scanty and high-priced water supply could well adopt the practice more widely.

THE SUBIRRIGATION METHOD

Alfalfa is usually irrigated from the surface by one of the methods previously described. However, a small percentage of alfalfa lands—probably not more than 5 percent of the total—is irrigated from below.

Frequently the seepage water from porous, earthen ditches and the waste water from irrigated areas passes through the subsoil of lower fields sufficiently near the surface to subirrigate them. In other places these seepage waters collect at the lower levels and raise the ground water near enough the surface to supply the plants with the needed moisture. It is questionable whether alfalfa growers should place much dependence on this mode of supplying moisture. What is gained in not having to irrigate usually is more than lost in damage done to both soil and crop by the rise of the ground water, which is almost certain to be followed by an accumulation of alkali near the surface if it is at all prevalent in the soil. Moreover, the fact that an alfalfa field subirrigates is usually an indication that the ground water is rising dangerously near the surface, and observations should be made to determine whether the level is above the danger limit.

Alfalfa is subirrigated also from the flood plains of streams. On bottoms the danger from alkali is not great because little is present and the height of the ground water is governed by the condition of the stream. It often happens that when the water table is at its highest point the alfalfa plants are dormant or nearly so and therefore are not injured readily.

In the vicinity of St. Anthony, Idaho, there is a subirrigated area of about 30,000 acres. Water is conveyed to the farms of this tract in the usual way and is then diverted into shallow field ditches. These ditches are about 3 feet wide and 6 inches deep; they are spaced 100 to 300 feet apart and extend lengthwise of the field. Crops are planted in the spring when the ground water is low; then a stream is turned into each ditch and kept there day and night until the ground water rises near enough to the surface to supply the moisture needed by the plant roots. Thereafter the height of the ground water is regulated by the quantity of water turned into the supply ditch. The rise and fall of the ground water is determined by means of small boxes set in the ground 3 to 5 feet deep. Twenty to thirty boxes usually are required for each 80-acre farm. About half the water is turned out of the main canal prior to September 15 to permit the land to dry for the harvesting of crops. After the crops are removed, a small stream is left running in the main canal all winter, but notwithstanding this supply the ground water usually falls 6 to 20 feet below the surface during the fall and winter months. The canals supplying this area divert 11 acre-feet of water per acre during the irrigation season (May to September, inclusive) and 3 acre-feet per acre during the nonirrigating season, an annual total of 14 acre-feet per acre. Somewhat similar methods are used in other areas, as for instance in the San Luis Valley, Colo., but in all cases they are dependent for their success on especially favorable conditions.

SPRAY OR SPRINKLER IRRIGATION

Irrigation of field crops by portable sprinkler outfits has attracted attention in recent years, especially in some sections of California. Exceptional requirements limit the use of this method for the irrigation of alfalfa, and special advice should be obtained by farmers interested in adopting it.

QUANTITY OF WATER REQUIRED

Alfalfa requires more water than most crops. This is accounted for readily by the character of the plant, the rapidity with which it grows, the number of crops produced in a season, and the heavy seasonal tonnage obtained. Its roots are not only deep but well-distributed to draw plant food from the most fertile layers of soil and moisture from the wettest layers, while that part which is above ground is well provided with leaves from which water is transpired in large quantities. The rate of growth varies with the soil, temperature, and other factors, but under favorable conditions a crop matures in about 35 days. In some localities killing frosts shorten the growing period to such an extent that only one or two cuttings can be made in a season. Ordinarily, however, when the deficiency in rainfall is made up by irrigation and the period of growth is long enough, three to six crops are harvested, yielding a seasonal total of 3 to 7 tons per acre.

There is a wide variation in the seasonal quantity of irrigation water required by alfalfa. Two of the most influential factors are climate and soils. Temperature determines the length of the growing period and the number of crops that can be grown yearly, while precipitation, if it is effective, lessens the quantity of irrigation water needed. The quantity of irrigation water required under an effective rainfall of 12 inches is obviously less than that under an effective rainfall of 3 inches. Soils cause a variation in that more water is wasted in irrigating pervious than impervious soils.

Many experiments have been made by the Division of Irrigation to determine the water requirement of alfalfa. Some of these experiments were made in tanks under controlled conditions, others on plots under partially controlled conditions, and the remainder on selected fields.

The results from the tank experiments seem to establish the following facts: (1) For the first few months the energies of the plant are devoted more to the establishment of a root system than to the production of stems and foliage; (2) the least demands for water occur in early spring, by reason of low temperatures and other unfavorable conditions, and immediately after a crop is harvested; (3) the demand for water is fairly constant during growth but tends to increase slightly up to the blooming stage; and (4) within a narrow range the water consumed by the alfalfa, per ton of hay produced is fairly constant regardless of the quantity applied during the season or at each irrigation.

Experiments to determine the water requirements of alfalfa were carried on in southern Alberta by the Canadian Government. The mean results of four seasons of plot experiments are shown graphically in figure 20. The plot which received no irrigation water, as indicated in the first line at the left of the graph, and 0.4 foot of rainfall, drew on the soil moisture to the extent of another 0.4 foot in order to produce one-third ton per acre. The second plot received 0.35 foot of irrigation water in addition to the rainfall but also drew on the soil moisture for 0.45 foot to produce a yield of 1.7 tons per acre. Similarly the third, fourth, fifth, and sixth plots, which received, in the order given, increased quantities of irrigation water, likewise obtained more or less additional moisture from the soil. In the seventh plot, which received a total quantity of 2.4 feet, the needs of the plants for water

seemed to have been satisfied, since there was slightly more moisture in the soil at the close of the season than at the beginning. Nevertheless, plot 8 required 2.9 feet of water in all to produce the maximum seasonal yield of 5.7 tons per acre, although nearly 0.3 foot remained in the soil unutilized. Beyond this stage the additional water applied tended to decrease slightly the seasonal yield.

In similar experiments at the Montana Agricultural Experiment Station, Bozeman, Mont., the yield varied from 4.61 tons per acre with the application of 1.2 acre-feet of irrigation water and rainfall to 7.68 tons per acre when a total of 3.7 feet was applied.

In the Yellowstone Valley, Mont., two heavy crops and a third light crop can usually be grown. Nearly half of the yearly precipitation of 14 inches occurs in April, May, and June, so that the first

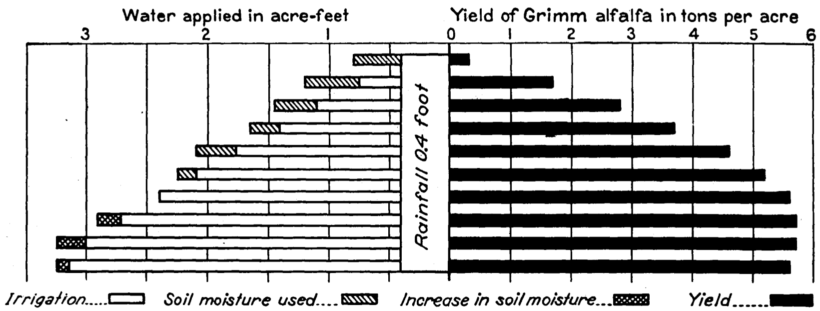

FIGURE 20.—Yields of alfalfa obtained by the use of various quantities of water at Brooks, Alberta.

crop is far advanced before irrigation water is required. Experiments carried on for 3 years showed that with an average seasonal application of 2.56 acre-feet of water per acre, including rainfall, the average yield of hay was 4.15 tons per acre.

In similar investigations in northern Colorado the six alfalfa fields which produced the highest yields (4 to 6 tons per acre) used 3.23 acre-feet of water, including rainfall. In the lower Arkansas Valley of Colorado an average yield of 3.21 tons of hay per acre was secured with the use of 3.23 acre-feet of water.

Recent experiments at the Scottsbluff field station, in western Nebraska, show the water requirement of three crops of alfalfa, irrigated three times yearly, to be 25.89 inches. This quantity produced field-cured hay at the rate of 5.2 tons per acre, or about 0.203 tons for each inch in depth of water. These results are averages obtained through 5 years of intensive studies of moisture on ¼-acre plots of 3-year old alfalfa in which consideration was given to water storage in the soil at the beginning of, during, and at the end of the season, together with the irrigation water and rainfall received during the season. Irrigation was accomplished by flooding. The three applications per season varied from 8 to 12 inches each, one irrigation being made for each cutting of hay. Each crop usually consumed all the available moisture within the root zone, and because of insufficient moisture the subsequent crop made little or no growth until more water was received. The best crop yields were obtained during the

season of 1935, when a total (two-plot average) of 6.06 tons of hay was produced with a water use of only 23.48 inches; this amounted to 0.259 tons for each inch of water used. The poorest yields were obtained in 1936, when 22.7 inches produced only 4.04 tons per acre, or 0.178 tons for each inch. The 25.89 inches used did not include

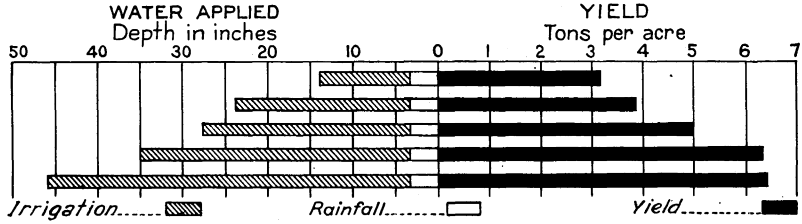

FIGURE 21.—Relationship between average yield of alfalfa and average quantity of water applied at Gooding, Idaho.

water consumed by the off-season growth or growth occurring after the third cutting and before the fall frosts. Three years of data indicate that for this off-season growth, the use, depending on temperatures, availability of moisture, and length of period, may vary from 2 to more than 5 inches, the average being 3.78 inches.

The results of tests to determine the most economical use of irrigation water on alfalfa in southern Idaho are shown graphically in figure 21.

In New Mexico a seasonal yield of 5 to 6 tons of hay per acre requires on an average about 4.25 acre-feet of water.

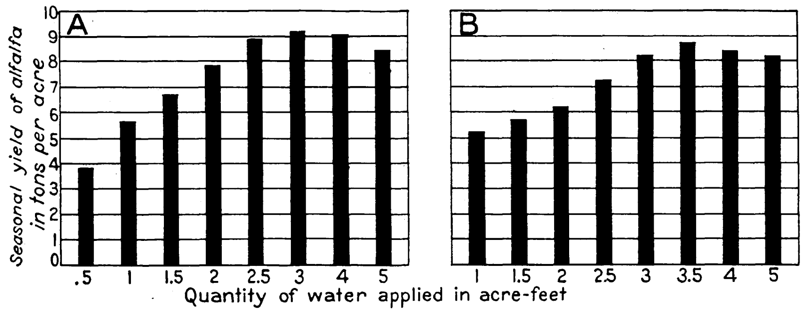

FIGURE 22.—Results of plot experiments (A) at Davis, and (B) at Delhi, Calif.

The results of plot experiments at Davis and Delhi, Calif., are shown in figure 22.

NUMBER AND FREQUENCY OF IRRIGATIONS

Except during its dormant stages, alfalfa should be furnished with sufficient water to enable it to grow continuously at a maximum rate. After the cutting and removal of a crop less water is needed until the foliage of the subsequent crop again demands its quota of water. Except during this interval, however, about the same quantity of water is needed during the entire period of growth.

Alfalfa commonly receives careless treatment at the hands of western irrigators. When water is available and is not needed for other crops it usually is turned on the alfalfa fields or meadows whether they need it or not. There is no question that yields of alfalfa and the life of the stand might be increased considerably if more care were used in finding out when to apply water. In each kind of soil and under any given set of climatic conditions there is a certain range of soil moisture which will give the best results. Unfortunately in many sections the farmer is not able to exercise his choice in the matter, as he has to make what use he can of the water when it is available.

There is a considerable range between the moisture percentage at which the soil is too wet for a normal growth of the crop and that at which it is too dry. To use water most economically the limits of soil-moisture percentages within which the crop grows best should be determined, and the practice adopted should be such as to keep the soil moisture within these limits at all times.

It is impossible to maintain uniform soil-moisture conditions for any length of time, but the moisture can be kept within the useful range. Under the present unskillful practice the soil is likely to receive too much or too little water, or else it is deluged with cold water at a time when it needs only heat and air. The number of irrigations required depends upon the depth and nature of the soil, the depth to ground water, the number of cuttings, and the rainfall, temperature, and wind movement. Both number of irrigations and the time of irrigating depend to a considerable extent on the number of cuttings and the time of cutting. It is necessary to have the fields dry enough to permit the use of machinery for harvesting the crop, and consequently they cannot be irrigated just before the cutting; but if light soils are not irrigated before the cutting, they may not retain enough moisture to start the new crop and maintain its growth until the old crop is removed. Usually it is considered the better practice to irrigate as late as possible before the cutting and again after the crop is removed if more water is needed.

Other things being equal, more frequent waterings are required in the warm sections of the Southwest than in the cooler portions of the North. The number of irrigations per year for alfalfa ranges from 3 in Montana and Wyoming to as many as 12 in parts of California and Arizona. In localities where water is scarce during part of the season the number of irrigations, as well as the amount of water used each time, depend on the available supply. It is a common practice to apply frequent and heavy irrigations in the spring, when water is abundant, and to water less often and more sparingly when the supply is low. Alfalfa is a deep-rooted crop, and where the soil is deep a large quantity of water may be stored in the soil. In some cases water may be available for irrigation only in the fall or early spring. Heavy irrigation of alfalfa on deep soil at such times may insure fair crops even when water is not available during the growing season.

RISE OF GROUND WATER AND ITS EFFECTS ON ALFALFA

In their natural state the typical soils of the arid region are characterized by their looseness, dryness, and absence of high water table. The diversion and use of large quantities of water in irrigation soon change some of these natural conditions. A part of the flow in earthen

channels escapes by seepage, and still larger quantities percolate into the subsoil from heavy surface irrigations. The waste water from these and other sources collects in time at the lower levels and raises the ground water. Usually this rise is noticed first in wells, a permanent rise of 5 feet in a year being not uncommon.

This rise of the ground water is an advantage, provided it does not go too high. It lessens greatly the cost of sinking wells, reduces the quantity of water needed in irrigation, and furnishes a reservoir from which water can be pumped to supply other lands.

It is not until the water level encroaches upon the feeding zone of valuable plants that its injurious effects are felt by the farmer. Its near approach to the surface may prove so disastrous that the upward trend should be noted with the greatest care.

One of the best ways of making such determinations is by means of test wells. Permanent observation wells from 2 to 4 inches in diameter should be sunk in different parts of the field, and at regular intervals the elevation of the ground water in each should be noted. Where the subsoil is a clay or a clay loam no lining will be necessary other than a joint of drain tile or a short wooden tube. Where the subsoil is loose, it may be necessary to line the wells. Downspouting or other lightweight galvanized pipe, wooden boxes, or small drain tile may be used for this purpose. The wells may be connected by a line of levels, the elevations being taken on the tops of stakes driven beside the wells. These well records, if taken at monthly intervals for several years, will show at a glance not only the position of the water table, but also its rise and fall throughout the season. Whenever it is found that the water table stands for any considerable time at less than 4 feet from the surface there is reason for alarm, and measures should be taken to prevent the accumulation of seepage waters or to remove the surplus by drainage.

There is some difference of opinion as to what subsurface depth marks the danger line for alfalfa. It has been shown by soil physicists that water may be withdrawn by capillarity from saturated soils to depths varying from 4 to nearly 5 feet, depending on the character of the soil. This fact is important because when the ground water is brought to the surface and evaporated the salts held in solution are deposited at or near the surface. If these salts are sodium salts, they are usually grouped under the common term "alkali," and their accumulation at and near the surface will in time destroy the alfalfa. Therefore when alkali is present in harmful quantities in the ground water, the water should not be allowed to rise within 5 feet of the surface.

In soils free from alkali but saturated with water there is not the same necessity for holding the ground water continuously below the so-called "danger line." Numerous cases might be cited to show that the rise of water within a foot or two of the surface for comparatively short periods of time does little injury to the plants. On the other hand, wherever water stands continuously during the irrigation season within a foot or two of the surface it is almost certain to destroy in time that part of the taproot which is submerged.

The remedy for a high ground-water level is drainage by means of deep ditches, covered tiles, or pumping from wells, but much can be accomplished by the exercise of measures which tend to prevent waste water from accumulating in the soil and subsoil.

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